Final Report

Grant No. SP179-08277

AUDIO-TUTORIAL REFERENCE MATERIALS IN BIOLOGY (CELL DIVISION)

Frank Franks, Project Director

Robert Glass, Project Assistant

American Printing House for the Blind

1839 Frankfort Avenue

Louisville, Kentucky 40206

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NATIONAL SCIENCE FOUNDATION

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NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT

NSF FORM 98A

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PART I–PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
American Printing House f/t Blind 1839 Frankfort Avenue, Box 6085 Louisville, Kentucky 40206	Physically Handicapped in Science	SP179-08277
	4. Award Period From 7/1/79 To 12/31/80	5. Cumulative Award Amount $35,884.00

6. Project Title

Audio-Tutorial Reference Materials in Biology (Cell Division)

PART II–SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

The principal objective of this project was the development and evaluation of self-instructional materials in cell division for use by visually handicapped students. Six mitosis and 14 meiosis models (color coded tactile schematics in relief)--each depicting a phase of cell division--with accompanying self-instructional cassette tapes, braille and large print glossaries, and a print copy of the tape scripts with labeled drawings for use by teachers and sighted readers were the primary products of this project. A subordinate objective was the preparation of guidelines for the subsequent development of self-instructional materials for prebiology students and for other physically handicapped students who can utilize such materials in conjunction with other modalities.

The models and tapes were reviewed by science experts to insure content accuracy, structures displayed on the models were empirically tested for tactile legibility, and the reference package was evaluated by participating teachers and by legally blind student project assistants who used the materials. The evaluation interviews with teachers and students revealed their enthusiasm for the materials and the appropriateness of the materials for visually handicapped students. Critiques by content experts confirmed that the materials have a universal reference value for all biology students in the mainstream.

A guidelines format was adapted from the student/teacher interview form to provide categories of checklist items for potential developers of self-instructional materials for upper elementary and prebiology students.

PART III–TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (√)	Approx. Date
a. Abstracts of Theses	X				
b. Publication Citations				X	when avail.
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
e. Technical Description of Project and Results		X			
f. Other *(specify)* Scripts and Representative Models				X	Jan. 1981

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Frank L. Franks		Jan. 1981

Introduction

Problems in Science Instruction

Providing science curricula for blind students equivalent to that of sighted students is frustrated by the highly pictorial science texts. Many of these texts enjoy wide use and popularity but do not lend themselves to meaningful transcription in braille. Textbook inspections have confirmed that increasing numbers of concept-related activities are appearing in the science curriculum. The expanding science curriculum for sighted students, however, is compounding the educational problem for blind students. As the number of concept-related activities and processes pictorially presented in science texts increases, the overall percentage of activities and schematics which can be readily interpreted by blind students decreases. The inverse proportion is due largely to the highly visual illustrations in textbooks which have facilitated learning for sighted students.

Inspection of commercially available biological models reveals numerous three-dimensional wooden or plastic models. These three-dimensional models are typically designed for visual representation, frequently lack adequate tactual legibility, and are usually quite expensive. Embossed representations of models which appear in braille textbooks often are illegible due to inherent limitations of two dimensional representations of three-dimensional objects and the addition of confusing indicator lines and dots. These indicator lines are easily confused with the outline of the model itself and often the result is a meaningless maze of raised lines and braille dots.

The major problems underlying commercially available instructional materials for blind students in science result from the following conditions: the highly-visual nature of science textbooks, and the lack of appropriate tactile aids necessary for blind students to interpret visual concepts and information presented in the textbooks.

Needs in Science

The following excerpt from a position statement (from proceedings from the working conference supported by an NSF grant on SCIENCE EDUCATION FOR HANDICAPPED STUDENTS held April 3-5, 1978, in Washington, D.C.) provides a baseline for consideration of instructional needs for handicapped students in science.

> Handicapped children have a right and a need to learn basic science content and skills. Evidence presented at the conference indicated that handicapped children are interested in and capable of learning science. Handicapped students have similar needs to those of non-handicapped students, therefore, it is necessary that equal education opportunities be offered to handicapped students.

> Science courses should be an integral part of the education of all handicapped students from kindergarten through high school. Physically handicapped students should receive the same comprehensive exposure to the various fields of science as do non-handicapped students. The teacher who teaches science to the physically handicapped must possess a strong comprehensive science background. Science teachers utilizing multi-sensory instructional techniques and laboratory-centered programs are able to effectively teach physically handicapped students in regular classes or special classes. The instructional strategies, techniques and procedures found to be effective with the physically handicapped in science are those also found to be effective with the non-handicapped student. A great need exists for the dissemination of educational information about science materials, teaching aids, techniques, conferences, workshops, etc., to both the regular and special education teachers who teach science to the handicapped students.

One of the most pressing needs in the education of the visually handicapped is finding alternate methods of presenting material which is usually exhibited visually. The sighted student of biology typically relies upon a number of visual learning aids to attain the curriculum objectives. Textbook pictures, diagrams, and illustrations, along with three-dimensional models and laboratory specimens, are major contributories to the learning process. Alternate methods of presentation and specialized materials or aids must be employed if blind students are to obtain the valuable information normally imparted through these media.

The need for instructional materials in the biological sciences was emphasized by participants in the Institute on Instructional Materials Development in Science for Visually Handicapped (Franks, 1970), held at the American Printing House for the Blind. Members identified the biological sciences as an area with a critical shortage of educational materials. In particular, they cited the lack of satisfactory tactile models of representative species of the major plant and invertebrate animal phyla. Also recommended were self-instructional materials which would afford the blind student a greater measure of independence.

Project Objective

This project was undertaken in response to an urgent need cited for audio-tutorial reference materials which blind and visually handicapped students can use without teacher assistance in the rapid-paced mainstream classroom. This 18-month project was funded by the Physically Handicapped in Science section of the National Science Foundation. Work on the project began in July 1979 and was completed in December 1980. The principal and subordinate objectives were:

1. Principal objective

To develop and evaluate self-instructional reference modules in cell division, with models (color coded, tactile schematics in relief) which would be produced at the American Printing House for the Blind and made available to legally blind students throughout the United States.

2. Subordinate objective

To develop a format and guidelines for the development of self-instructional reference materials for upper elementary and junior high prebiology students, with implications for other physically handicapped students who can profit from such materials.

Materials Description

The materials developed in this project consist of 6 mitosis and 14 meiosis models--each depicting a phase of cell division--and accompanying self-instructional tapes. The test models were molded of 15-mil, high impact styrene by a vacuum-forming process and averaged 9 inches (22.9 cm) in length on their longest sides. Maximum relief was approximately 1 inch (2.5 cm). Chromatic coding was employed to maximize the color and luminance contrasts previously found effective by low vision students on other aids.

The accompanying tapes (recorded at 1 7/8 ips) focus on the critical events occurring in each phase of cell division. Each tape script is consistent in its use of format, which includes: phase overview, introduction, model orientation, content section, summary, and unit tests (with answers). Large print and braille glossaries were prepared for student use. A print script with labeled diagrams was included for use by a sighted reader or teacher.

The models were developed by the project director and by two science consultants who prepared the initial prototypes and test models. The consultants independently drafted the tape scripts and prepared the final scripts after their review by content experts and their evaluation in the field. These consultants were:

Dr. Elva Ruth Gough
Educational Vision Consultant
Dekalb and Warren County Schools
Box 254
Smithville, TN 37166

Mrs. Rebecca Hunton
Science Department
Indiana School for the Blind
7725 College Avenue
Indianapolis, IN 46240

In its October 1980 meeting, the American Printing House Educational Aids Committee approved the project materials for production, with models constructed in polyurethane. The materials will be available to blind students across the United States and throughout the world.

Project Operation

A number of preliminary activities were conducted. Several of the activities carried over into the developmental and evaluation phase.

1. More than 40 volumes of biology texts and reference books and materials were inspected to identify critical structures and events occurring in each developmental phase and to determine the appropriate information to be included in the program content. These references are listed in Appendix A.

2. A systematic procedure (Franks, 1975) developed at the American Printing House for identifying, classifying, adapting/developing, evaluating, and producing educational aids in science was reviewed. This procedure provided the foundation for project operation. It details an operational strategy for integrating classroom observation, teacher expertise, relevant research, and educational technology in the development of the instructional materials.

3. Materials in cell division (mitosis and meiosis) composed of prototype models and accompanying instructional units were developed at the American Printing House. An earlier set of less sophisticated models (Franks & Murr, 1978), which were tested for legibility and found to be highly discriminable, provided specimens for these models. Symbols were employed which approximated simplified biological structures in cell division as seen under a light microscope. The models emphasized simplicity, but offered additional cues where complexity occurred. Texture, size, shape, and relief were used for maximum legibility. Chromatic color coding was employed to maximize color and luminance contrasts for low vision students.

4. Instructional unit drafts for each phase of cell division were written and were recorded on cassette tapes. Interphase, the first model and tape, was written to serve as an introduction to mitosis as well as the first reference unit. The content level was prepared for high school students who were in or who had completed the first course in general biology.

5. Glossaries of biological and scientific terms appearing in the units were drafted.

6. Six nationally prominent science educators and biologists were invited to serve as a content advisory committee to the project. These experts were:

Dr. Paul C. Beisenherz, Associate Professor
College of Education
University of New Orleans
New Orleans, Louisiana 70122

Dr. Dean Brown, Professor
Science Department
Colorado State University
Fort Collins, Colorado 80521

Dr. Kenneth Ricker, Associate Professor
Department of Science Education
University of Georgia
Athens, Georgia 30602

Dr. Ronald Simpson, Professor
Department of Science Education
North Carolina State University
Raleigh, North Carolina 27607

Dr. Irwin Slesnick, Professor
Biology Department
West Washington University
Bellingham, Washington

Mrs. Dorothy Tombaugh, Biology Teacher
Lyndhurst Public Schools
Lyndhurst, Ohio 44124

Materials Development and Evaluation

Evaluation of Models for Legibility

The previous inspection of biology texts and reference materials identified structures to be symbolized on the models. Proposed structures on seven initial mitosis models--corresponding to six phases in miotic development--were specified. These were listed on a critique form and sent to the content advisory committee for their comments. Committee members were asked if critical structures were identified and if the structures represented were named correctly. They were asked for any additional comments they wished to make. They generally agreed on structure content and on terminology. Questions and comments were made relating to disappearing membranes, spindle rays, and occurrence of some events in phases.

Symbols varying from those previously evaluated by Franks (1978) were tested for legibility. Pseudo-models and materials were constructed for use in testing the legibility of the symbols.

Students who were in or had completed biology or a related science course participated. To insure that the tasks were performed tactually, students with useful residual vision used shades as in the previous legibility tests of biological symbols cited above. A total of 24 students were included in the mitosis evaluation. A breakdown of students by age, grade range, and sex is presented in Table 1.

Table 1

Mitosis Symbols

N	Age range	Mean age	Grade range	% female	% male
24	14-21	17	9-12	37.5	62.5

A total of 11 students was included in the meiosis evaluation. A breakdown of students by age, grade range, and sex is presented in Table 2.

Table 2

Meiosis Symbols

N	Age range	Mean age	Grade range	% female	% male
11	15-21	17.3	9-12	63.6	36.4

Overall performance on the two tests approached 100% correct performance, with only one incorrect response on one mitosis symbol. A breakdown for legibility by symbol for mitosis (N = 24) and meiosis (N = 11) is presented in Table 3.

Table 3

Symbol Legibility--Mitosis and Meiosis

N	Symbol	Percentage Correct
24	Cell Membrane	95.83
24	Centriole	100.00
24	Nuclear Membrane	100.00
24	Chromosome	100.00
24	Nucleus	100.00
24	Chromatid	100.00
24	Nuclear Membrane--Dissolving	100.00
24	Paired Chromatids	100.00
24	Protein Fibers/Astral Rays	100.00
11	Revised Centriole	100.00

N	Symbol	Percentage Correct
11	Metaphase I, Chromosome A	100.00
11	Metaphase II, Chromosome B	100.00
11	Homologous Chromosomes, Diplotene Stage	100.00
11	Chromosomes, Z-P Stages	100.00
11	Telophase II, Chromosome A	100.00
11	Telophase II, Chromosome B	100.00
11	Telophase II, Chromosome C	100.00
11	Telophase II, Chromosome D	100.00

A criterion of 85% correct response for each model part was previously established.

Evaluation of Script Content

In a meeting at the National Science Teachers Association Convention in Washington, D.C., the content advisory committee reviewed the models and the unit format and content.

The committee members were enthusiastic about the mitosis models. On content, they suggested that the authors consider:

1. Changes which will occur in biology textbooks as a result of new discoveries (e.g., two centromeres instead of one in prophase).

2. Effects of the expanding content in biology (e.g., more depth in content with increasing numbers of offerings in advanced high school biology) as well as simplified presentations (e.g., with meiosis especially) as biological content filters down in junior high (middle school) texts.

3. Inclusion of basic questions and answers related to uniqueness of the medium and the content, reference and/or thought-stimulating questions possibly, and of relation to real life and purpose where possible.

A subsequent project review meeting with the content advisory committee was held in conjunction with the National Association of Biology Teachers Convention in New Orleans. The meeting focused on "What are the weaknesses of the materials?" and "How can the materials be improved?" Participants suggested that:

1. The mitosis and meiosis content should be related to biology and to life (reproduction).

2. The <u>process</u> be summarized with a schematic, although this might not be needed if a short story (e.g., cell city anthology) introduction were provided.

3. A summary or review of each phase should be included instead of some of the questions now included as part of the content.

4. More examples related to rate of time of division of cells and variation in rates be included. Geometric progression should be considered.

5. The content is technical and could be overwhelming for some students, and a multiplier effect could occur because of the number of sources used in preparing the scripts. The emphasis was on reduction and not on elimination of terminology.

Additional comments included:

> The problem of motivating mainstreamed students to a high level of participation in evaluation was recognized. Much of the students' time--particularly with meiosis--must be spent on their own. A reward system of some kind received positive response.

Pilot Test Activities

Pilot Test Activity I was conducted in a summer school science program with 27 students using the mitosis models and tapes. It was very successful. The results confirmed that the materials were suitable for field evaluation. Five of the students included had normal vision, 13 were large print readers, and 9 were totally blind or braille readers. A preliminary breakdown of performance on mitosis from reports of the evaluating teacher is presented in Table 4.

Table 4

Concept Understanding on Mitosis Tapes and Models

Concept understanding	Regular vision	Large print	Braille
Good/Excellent	1	7	7
Relatively good	1	4	1
Superficial	1	1	1
Poor	1	1	0
Lacks the concept	1	0	0

When each student had gone through a tape and could answer all of the questions, he summarized each phase. The summary was to re-establish what he had learned and was for his use. Upon completion of the mitosis unit, each student prepared a brief description and summary of the events leading up to and during cell division. The teacher evaluated this summary and had the student sequence or order the models. These pilot test activities were conducted by:

Mr. James Chudomel (formerly science teacher: Montclair Academy, N.J.)
237 1/2 Mt. Lucas Road
Princeton, N.J. 08540

Pilot Test Activity II was conducted with 11 students (4 braille, 7 large print) at the Indiana School for the Blind who had used mitosis and meiosis materials in their biology class. The purpose of this evaluation session was to get student critiques on the field evaluation forms and procedures, to get suggestions for improving the overall project materials, and to get student input on preparation of the glossaries.

Student evaluation consisted of the following activities:

1. Sequencing the models in order by phase.

2. Using the models in writing open-ended summaries by phase or event.

3. Critiquing the evaluation/interview form items.

Students had no difficulty in preparing the summaries or in sequencing the models. They reacted positively to the evaluation form--its flexibility and lack of undue emphasis on rote memory of the biological terms used in the units. However, they indicated that they had initially experienced difficulty with the number and variety of biological terms presented.

Students had several specific suggestions for the glossary. Their suggestions were:

1. Make the glossaries available in large print <u>and</u> braille. (No student requested a taped glossary.) Because the terms were new, difficult to spell, and numerous, students expressed unanimously the need for a glossary they could inspect visually and/or tactually as they used the tapes.

2. Include all new and difficult biological terms. These terms presented greater problems for braille students and they wanted to see them spelled correctly in braille. Low vision students expressed a similar dilemma, although not as emphatically as braille students. They wanted to see the words spelled correctly in print. The class felt that such a glossary would be even more valuable for students who use the materials independently.

3. Spell and define the word the first time it appears. The class suggested a procedure for use of the braille and large print glossaries:

   > Indicate each specialized term in the text with a "click." The student can stop the tape and find the term in the glossary without losing his place. He can study the term and replay the text portion until he is ready to go on.

Field Evaluation and Results

The materials were evaluated by 21 (15 braille, 6 large print) students in residential and public school settings who used the models and taped programs. Emphasis was given to collecting information from braille/tactile students since greater instructional problems were believed to exist for them than for low vision students. The students participated as project assistants. The residential school students (Field Evaluation Group A) were evaluated separately to provide for more observation and student interaction during use of the materials than was possible with public school students (Field Evaluation Group B), who most often were served by itinerant teachers. A list of these students and participating teachers is included in Appendix B.

Field evaluation group A. Seven braille and 2 large print students from the Georgia Academy for the Blind participated in the evaluation. A breakdown by science level, reading medium, and grade is presented in Table 5.

Table 5

Student Project Assistants--Group A

Student	Science level	Medium	Grade	Comments
A	Prebiology	Braille	8	No vision
B	Prebiology	Braille	9	Light perception
C	Prebiology	Braille	9	No vision
D	Prebiology	Braille	10	No vision
E	Prebiology	Braille	10	No vision
F	Prebiology	Braille	10	No vision
G	Prebiology	Braille	11	lp lp
H	Biology	Print	11	lp 20/80 (near point)
I	Biology	Print	10	20/150 20/150 (near point)

The major differences between Evaluation Group A and Group B were that the student project assistants in Group A:

1. Included a number of prebiology students.

   The students were designated by their science teacher as prebiology students who will eventually take biology. The project director was interested to learn if prebiology students could use the materials following the content format.

2. Met initially in group sessions with the project director to ensure that the prebiology students could handle the content. (One prebiology student did drop out.)

3. Were observed using the mitosis models by the project director as they listened to tapes.

4. Held group critique sessions after listening to each of the first four (mitosis) tapes.

5. Were able to meet with the project director individually or in groups on a daily basis.

6. Had a time limitation of 2 weeks, including one weekend, to complete the project.

Students in Group A were given a very brief review of the basic cell. Mitosis and meiosis were identified as kinds of cell division. With this brief introduction, students began using the tapes and models. Interphase, prophase, metaphase, and anaphase were presented in three group sessions to ensure that students were able to comprehend the materials and procedures. Since most of the students had little prior related instruction and since the materials were prepared for biology students, it was anticipated that the prebiology students might experience frustration. The initial group sessions were to reduce this frustration and to identify problems prebiology students might have. At the end of the third session, students were allowed to check out materials to take to the dormitories for independent use.

Students were given the following instructions:

> Go through each set of tapes using the models. Since the tapes are self-instructional, you may go through them at your own pace. After you have gone through each tape using the model, you will summarize the phase. Each tape is about 20 minutes in length. This summary is to re-establish what you have learned and is for your own use. When you have completed the mitosis unit and tapes, you will prepare a brief description/summary of the events. The supervising teacher will evaluate the summary and will ask you to sequence the models in the correct order. The teacher will record your performance in sequencing the models. You may use your summary in sequencing the models. The teacher will send us your summary of events. It is not necessary for you to put your name on the summary. The teacher will verify that you have completed it. When you have completed the mitosis unit, you can proceed with meiosis following the same procedures.
>
> We also want your evaluation of the materials. Your input will not only determine the changes made in these sets of materials but will have a significant impact on whether we pursue development of additional similar kinds of reference materials in science. In a final interview we will want you to respond to such questions as: Do you think that too many scientific or biological terms are included? Which terms should be eliminated? Which terms should be included in the accompanying glossary? (There

is a "click" on the tape after each term we have listed for the glossary.) Do the questions included in the tape help? Are there too many? Which ones should be eliminated? What suggestions do you have for improving the materials? Would you like to have more of this kind of instructional materials developed?

Criticism by students in initial group sessions was related to unit overviews and vocabulary and resulted in the following suggestions:

1. Include a simple overview in the introduction of what the unit (e.g., mitosis) is about--one that summarizes using a minimum of biological terms.

2. Include a similar phase overview at the beginning of <u>each</u> tape with an additional summary--in simple language--of what has been covered on previous tapes. For example, Tape 3 in a series would highlight or summarize sequentially the events in Tapes 1 and 2 before it gives the overview for Tape 3. This is important because there may be a significant time lapse between (use of) models and tapes, and all of the tapes may not always be available when the student wants to use them.

Students did <u>not</u> complain about the extensive use of scientific vocabulary in the tapes. They did question if such extensive use will be necessary in prebiology materials. Some students stated that since these are reference materials, the terminology should be included for those who may use it. However, simpler explanations should be included for those who don't need all the detail.

There was emphasis on <u>not</u> being able to spell the terms and the need for a braille or large print glossary to have at hand when going through the tapes. (One student reported that many of the terms were not in his dictionary.) Students liked the "clicks" identifying terms to be included in the glossary. Another related response was that a student can check the spelling of a term immediately in the glossary if he wishes, stopping the tape very briefly or perhaps not at all. To compare the pronunciation and spelling of a term, the student can back up (rewind the tape) as many times as necessary.

Although it was apparent that students experienced some initial difficulty with the unfamiliar biological terms, little frustration was evident. The students quickly learned to focus on events--as instructed--and concentrated on terms and definitions related to critical events. Observations suggested that students gained an operational understanding of critical events in a phase before they were able to verbalize the events. In-group discussion and interaction in the first three sessions improved verbalization and use of specialized terms.

By the third session with Tape 3 (Anaphase) an air of guarded confidence began to emerge in several students. Some began to verbalize almost freely using correct biological terms in describing and summarizing events. Students began to look ahead to completing their overall summary of mitosis, and the question of spelling the terms correctly again arose. The initial lack of familiarity with terminology appeared to present little difficulty in following the tapes and locating structures on the models, even with Tape 2 (Prophase), which is complicated and contains more structures and events than the other phases in mitosis. Correct spelling of terms remained a persistent question.

Although little difficulty was observed locating structures on the models, students were monitored during the model orientation segments of the tapes in the group sessions. Students were observed occasionally checking other students' identification of structures or asking other students for confirmation that the correct structure had been found.

The students were unanimous in their statements that the models "make the content easier to understand." This is an interesting interpretation of the role of the models in the materials package. At this point students elaborated on the poor quality and lack of legibility of raised line drawings in science textbooks, and on the problems of relating the drawings to text content and vice versa. Particularly, braille students emphasized the difficulty in identifying diagrams and their parts with the maze of labels and raised lines on the diagrams.

One student's enthusiastic response upon inspection of the Interphase model was, "You can really feel something on the model that you can identify." All students praised the clarity of the uncluttered models as compared to raised line drawings in science texts. Another student observed, "When you are able to follow the raised line on the textbook diagram, you can't always be sure of what you are supposed to find." Low vision students also expressed difficulties in using cluttered diagrams in textbooks.

Students liked the format, particularly the question and answer exercises and the unit tests. Although they didn't always respond orally in the group, they were able to reinforce and verify answers. They liked being able to check their answers to questions immediately, particularly since they didn't have to write or braille every answer. Students stated that the repetition and question and answers enabled them to learn more easily. The short content segments followed by questions and answers and the relatively short tapes reduced boredom. One braille student noted that the consistency in format made the learning process easier--he was able to structure information mentally with a minimum of note-taking. Another braille student commented, "You feel good when you are able to answer a question correctly." Reaction to the bell tone in the question and answer activities was positive. Students did not report problems or confusion with the clicks and bells.

The students in Group A worked independently with the meiosis models and tapes. They submitted summaries to the participating science teacher and initially tried to sequence the 14 models without access to their summaries. Three of the 9 students succeeded. Two of these were braille, prebiology students and the third was a large print student enrolled in a biology class. When students had access to summary information, the teacher reported that all were able to sequence the meiosis models in order of events.

Field evaluation group B. Eleven (8 braille, 3 large print) legally blind students from California, Wisconsin, Massachusetts, Ohio, and Georgia participated as project assistants in evaluating the materials in mainstream classes in public school programs. The students either were enrolled in or had completed a biology course. Six public school teachers also participated with students in Group B.

Students in Group B generally were served by itinerant teachers who had limited time and student contact. The following evaluation procedure was included with the project materials sent to each participating teacher.

1. When a student has gone through a tape (recorded at 1 7/8 ips) and can answer all of the questions, have him summarize each phase in writing. This summary is to re-establish what the student has learned and is for his own use.

2. Upon completion of the mitosis (meiosis) unit, have the student prepare a brief description/summary of the events leading up to, during, and after cell division also in writing. Have him end the summary with an answer to the following question: What is the final outcome in mitosis (meiosis)? He may use his notes from 1. above.

3. When he presents his summary, ask him to use it to sequence the models in order of events. Please record his performance in sequencing on his summary.

4. Upon completion or during the evaluation, I will visit you for an interview or will send an interview form. On the form--one for you, one for the student(s)--we will want you to tell us the changes that can be made to improve the materials. Categories will be listed; you can check and comment. Your input and that of your students will determine the final content of the units. For example, students may feel that there are too many questions in the units. If so, we will reduce or eliminate questions. There is a "click" after each term included in the glossary. The student may want more or fewer of the terms included. The student interview form will have an item asking whether he wants the glossary on tape, in braille, or in large print.

You may have suggestions for making the materials more self-instructional, or you may feel from student response that the content is too difficult.

5. We want to receive the student summaries along with evaluations on the materials.

   These are reference materials and not curriculum materials. There are no incorrect answers as such. Your evaluation and that of the student is in terms of the value and appropriateness of the models and tapes as reference materials in biology.

Responses to evaluation items by public school teachers and by students in Group B were very similar. Responses for 6 teachers and 11 students in Group B are reported by category in Table 6.

Table 6

Group B (Public School Teachers & Students) Evaluation of Audio-Tutorial Reference Materials in Biology
(N = 17)

Evaluation Categories	% responding positively	% responding negatively	% not responding
Overall unit organization, content, and format	98.8	1.2	-
Instructions for use (Tape 1)	100.0	-	-
Overview section	100.0	-	-
Introduction section	100.0	-	-
Model orientation	97.1	2.9	-
Unit/phase content	94.1	5.9	-
Summary	100.0	-	-
Unit tests and exercises	97.1	2.9	-
Glossary	72.1	9.3	18.6
Models	86.3	13.7	-
Tapes	97.1	2.9	-
Labeling and packaging	54.8	45.2	-

Response patterns are very similar to those by students in Group A. Responses for the total group of participating teachers and students are summarized in the Discussion and Summary section. Specific differences in responses by teachers, by students in Group A, and by Group B are included.

Discussion and Summary

Some 30 teachers and students participated in interview/evaluations of the materials. The following summaries are based on responses from 28 (21 students, 7 teachers) participants. The categories correspond to those that the participants reacted to on the interview/evaluation forms.

1. Overall unit organization, content, and format.

   Students and teachers were unanimously positive in this category. The items included: (a) follows a logical sequence, (b) states essential information clearly, (c) explains effectively the phases in the process of mitosis and meiosis, (d) makes adequate use of the models as part of the program, and (e) utilizes a format which is easily followed.

2. Instructions for use (Tape 1)

   Again, teachers and students responded affirmatively. They indicated that the instructions provide essential information, are stated clearly, and follow a logical sequence.

3. Overview section

   Response was unanimously positive in this section. Participants felt that overview summaries clearly present the events in each phase and that essential information is included. Students especially liked the overviews, but suggested that they include only critical biological terms.

4. Introduction section

   Students and teachers indicated that the introduction section provides essential information for proceeding with the unit/phase. Some students wanted the explanation of "clicks" reduced--too much repetition.

5. Model orientation

   Again, participants responded that the section states instructions clearly and includes essential information. Students were most enthusiastic about the models and stated that they made the content easier to understand.

One braille student indicated that he would like more information on the shape and location of various structures.

6. Unit/phase content

Students and teachers generally were affirmative in their responses on the following items in this section: (a) conveys overall information clearly, (b) states explicitly specialized vocabulary and biological terms, (c) relates vocabulary and events to the content in each phase, and (d) relates clearly the use of the models in the content. There was mixed response to the item: (e) uses language/terminology which is too difficult for high school biology students. Students, however, were more concerned with spelling of terms than with their use. Students suggested that only critical terms be used in the overviews, otherwise their use was OK.

7. Summary

Students and teachers responded favorably to these summary items: (a) provides a helpful review of each phase/unit, (b) includes essential information, and (c) summarizes clearly the events of each phase. Students responded positively to the summaries--as they did to the overviews. They thought that the summaries were very valuable. Again, the suggestion to use only the critical terminology in the summaries was frequent.

8. Unit tests and exercises

Students and teachers were generally affirmative in their responses to the item "provides a helpful review of each phase and states questions clearly." Braille students particularly noted that the question and answer activities made learning easier and reduced the amount of note-taking necessary. Some students thought questions and answers in the middle of a section was confusing. Accelerated students felt that there was redundant presentation of information in the question and answer sections. Several indicated that they usually skipped over these portions. Braille students and a number of other students stated that they liked the immediate feedback provided by the answers.

9. Glossary

Students and teachers indicated that the glossary terms included provided adequate coverage of specialized and biological vocabulary. They stated, however, that they wanted glossaries available in large print and braille for use with the tapes. They were emphatic in this demand. They did

not feel that terms were always defined clearly in the text, but overall this would not present a great problem with a glossary available.

In regard to "too many difficult terms" and "definitions which are confusing," students responded that they felt that scientific terms are used in reference books and that they should be included here for those students who need them. However, students were definite about the inclusion of simpler explanations for those students who are seeking general information (e.g., what mitosis is and what happens in mitosis). They would like to see this kind of information in the overviews and summaries.

10. Models

Perhaps the most enthusiastic responses were on the quality and clarity of the models. Students felt that the models "made the tapes easier to understand." They indicated that the models were durable for testing purposes, that the size is adequate, although some students thought they could use smaller models, and that the symbols are appropriate for the structures they represent. Most students interviewed had questions concerning how the models were made and wanted to know if there would be more of the same kinds of materials. A number of students and teachers stated that the plastic (vacuum-formed) models were acceptable, others favored "solid" models like commercially available ones.

11. Tapes

Evaluation items on the tapes were: (a) lead-in is adequate, (b) pauses are of sufficient length, (c) reader's voice is acceptable, and (d) the overall quality of the tapes is adequate. Students and teachers were very pleased with the quality of the tapes. Some students suggested that the lead-in time was too long. However, a number of the students used variable speed players and had no complaints about lead-in time.

12. Labeling and packaging

Students and teachers interviewed agreed that labeling in braille and print in the near right corner of each model would be acceptable. The models used in evaluation were not labeled since part of the students' task was to sequence them in order of the events occurring in mitosis and meiosis. There was further inquiry regarding the inclusion in each script of a print diagram with labeled parts that the teacher or sighted reader might use if the student had difficulty in identifying a structure.

Packaging received the major criticism made by participants. Students and teachers want a carrying case of some kind with a specific place for each model and tape. Teachers may be carrying the models from school to school. Although students might not check out the entire set at one time, they want some provision for carrying and keeping what they do take home. This problem will be addressed by the American Printing House production department in the course of producing the set of materials.

Teacher interviews disclosed some comments and suggestions which were not presented in sessions when the student and teacher were together. The notable remarks related to content difficulty. Teachers of accelerated blind students felt that there was too much repetition and that this was demeaning or a putdown to these students. Some felt that there was too much detail, although the materials were logically and clearly organized. Some indicated that the materials were great for self-motivating advanced students, but were too detailed for the general biology students. Teachers were emphatic about spelling out specialized terms, with some suggesting an immediate spelling when the term appeared.

Student interviews revealed similar comments and suggestions. More advanced students supported teachers' views that there was too much repetition, including the question and answer sections. When queried, two students stated that they skipped those sections most of the time. Other students--including several braille readers--felt that the repetition and question and answer sections enabled them to gain the information with a minimum of note-taking. Their major concerns related to packaging, spelling out biological terms somewhere on the tape, and providing a braille and/or large print glossary. Accelerated students appeared to be selective in their use of repetitive information while other students relied on it, particularly the overviews and summaries. Although the meiosis section contained more than twice the number of models, students did not seem to feel that the section was more difficult. Some students reported sequencing the meiosis models prior to using the tapes!

Guidelines

A subordinate objective of this project was the preparation of guidelines for the development of subsequent self-instructional reference materials for visually handicapped students below the high school biology level. The guidelines have implications for students with additional handicapping conditions. The first section presents legibility considerations for the development of models or tactile schematics. The second section presents guidelines which focus on preparation of the content of the reference program.

Legibility Considerations

Information included in this section is summarized from a review of research relating to tactile legibility in an earlier publication by Franks (1979). A number of research studies in which empirical data were actually collected on blind subjects were examined to determine if they could be utilized in developing specifications for instructional aids in science. While none of the studies investigated problems specifically related to materials development in science, a number of clues underlying the tactile design of educational aids and/or displays on the aids were revealed. These guidelines were utilized in the development of biological models for blind students reported by Franks (1978). A sampling of relevant guidepoints follows.

Complexity of design. An immediate consideration in the design of any tactile aid is complexity. Tactile displays for blind students differ from visual displays for sighted students in that the blind student requires tactual interaction with the aid or apparatus. The studies investigated revealed that:

1. Contrast is the most important principle for raised-line diagrams and simplicity is possibly the second most important (Schiff, 1966).

2. On simple tests of tactual perception, both good and poor braille readers were found to perform equally well. Good braille readers were able to handle highly complex tactually perceptive material better than poor readers (Weiner, 1963).

3. Tactile arrays should be kept as simple as possible and the number of symbols kept to a minimum (Schiff, Kaufer, & Mosak, 1966; Wiedel, 1969; Wiedel & Groves, 1969).

Discriminability of symbols. Three types of patterns--point, linear, and areal symbols--are needed for graphic communication.

1. Discrete sets of point, linear, and areal symbols have been identified by Nolan and Morris (1971) in studies of tactual symbols for blind children. This reference also contains a review of related literature.

2. Discrete sets of symbols were identified by Gill and James (1973) and Wiedel and Groves (1969). Some point symbols which are often confused were identified by Jansson (1972). This reference also contains a review of literature on point symbols.

3. Blind students may have difficulty in recognizing differences in sizes of embossed dots as they appear in combination with each other or with certain other symbols (Nolan & Morris, 1963).

4. Textured sandpaper surface patterns of varying degrees of roughness are effective means of indicating different areas when size differences are moderate or large (Nolan & Morris, 1965; Schiff & Isikow, 1966).

5. There are probably large differences in degrees of noisiness among any set of discriminable textures (Lederman & Taylor, 1972)

6. A difference of two millimeters between histograms is barely adequate and actually too small for efficient interpretation (Schiff & Isikow, 1966).

7. Distance between dots (.90 inch), distance between braille cells in a line (.160 inch), and distance between lines of braille print (.220 inch)--distances occurring in Standard English Braille--are easily read (Meyers, Ethington, & Ashcroft, 1958; Weinstein, 1968).

8. Overall legibility of areal symbols remains good until the symbols are reduced to three-quarter inch squares (Nolan & Morris, 1963) or to one-half inch squares (Heath, 1958).

Tactile edges and lines. Raised lines (Nolan, 1971) and distinctive tactile edges (Schiff, 1966) are excellent ways of providing discriminable differences in area coding.

Stimulus redundancy. Redundancy involves encoding a message so that it contains more syllables or stimuli than the minimum necessary to transmit the information contained in the message. As diagram difficulty increases, additional redundancy appears to play a role in reducing errors. The best method of presentation in diagrams when "noise" level is high is the textured and raised format (Schiff & Isikow, 1966).

Scanning. Scanning or tactual inspection of tactile displays requires physical interaction for adequate comprehension of the symbols employed in the displays.

1. Although braille is often considered to be a difficult, cumbersome, and illogical system, children learn to read braille and to read it quite well (Ashcroft, 1960).

2. The braille character is the perceptual unit in braille word recognition (Nolan & Kederis, 1969).

3. The blind cannot "scan" a map but must form an image of it piece-by-piece (Sherman, 1965).

4. Size should be such that the user can cover a significant portion of a map with one hand and orient with the other hand (Wiedel & Groves, 1969).

5. Berlá and Murr (1976) describe the preliminary scanning operation of blind students as a two-handed, rapid, global, and unsystematic inspection with the finger tips. They found that training students to scan is effective before strong habits have been established.

Content Considerations

Teachers and students were unanimously pleased with the overall program organization, content, and format. They were able to respond with ease to the items on the interview/evaluation form. The following guidelines for content development incorporate information from reviews by content experts, from observations by project staff, and from interview/evaluation responses by participating teachers and student project assistants. Each guideline presents a statement or point of emphasis followed by specific items from the interview/evaluation form. Some of the items have been edited to make them more appropriate for use as a checklist by the specialist who would develop materials for student use.

Overall unit organization, content, and format. Appropriate content level, accuracy of information, and reasonable length of the program are critical.

The overall unit organization, content, and format:

1. Follows a logical sequence.

2. States essential information clearly.

3. Explains effectively the phases, processes, steps, and/or critical content.

4. Makes adequate use of models as a part of the program.

5. Is easily followed.

Instructions for use. Instructions should use vocabulary appropriate to target (grade) level, should minimize use of technical or specialized terms, and should be concise.

The instructions for use:

1. Provide essential information for use of all components.

2. Are stated clearly.

3. Follow a logical sequence in presentation of components.

Overview section. The overview section is very important. Braille students particularly relied heavily on this section.

The overview section:

1. Summarizes clearly the events and/or activities in each step or phase presented.

2. Includes information essential to understanding what the program presents.

3. Employs only critical biological or scientific vocabulary in this section.

Introduction section. This is a warmup section to get students going. It should be concise and simple.

The introduction section:

1. Provides information for proceeding with the unit or phase.

2. Includes essential information only.

Model orientation. A description of the model used, its content, and the location of structures displayed on the model are critical. At this point it is assumed that all models have passed legibility testing.

The model orientation:

1. States instructions and descriptions clearly and simply.

2. Includes essential information for locating structures on the model.

Unit/phase content. Students expressed more concern over spelling of terms than their frequency of appearance. When queried, however, some felt that less difficult specialized vocabulary should be used in prebiology materials.

The unit/phase content:

1. Conveys overall information clearly.

2. States specialized vocabulary and biological terms explicitly.

3. Relates vocabulary and events to the content in each phase.

4. Relates clearly the use of the models in the content.

5. Uses language which is appropriate for prebiology students.

Summary. Students stated that the summaries (along with the overviews) were very valuable and that they depended on them greatly. Again, they suggested that only critical terminology should be used in the summaries.

The summary:

1. Provides a helpful review of each phase/unit.

2. Includes essential information.

3. Summarizes clearly the events of each phase.

Unit tests and exercises. Braille students particularly noted that the question and answer activities made learning easier and reduced the amount of note-taking for them. Some advanced biology students felt that there was redundant presentation of information in the questions and answer sections. Several indicated that they usually skipped over these portions. Braille students and a number of large print students liked the immediate feedback provided by the answers.

The unit tests and exercises:

1. Provide a helpful review of each phase.

2. State questions and answers clearly.

Glossary. Students were insistent upon having access to a braille or large print glossary--not a taped version. Students did not object strenuously to the use of scientific or biological terms in the content if a glossary would be available. They did want the terms spelled out--letter by letter--in the text, and braille students wanted contracted spelling in the glossary.

The glossary:

1. Provides adequate coverage of specialized terms and biological vocabulary. (These terms are indicated on the tapes by a "click.")

2. States definitions concisely.

3. Uses definitions which are relevant to the content presented.

4. Defines terms operationally when appropriate.

Models. The models elicited the most enthusiastic responses. Students were impressed with the legibility and arrangement of structures.

The models:

1. Are of durable construction.

2. Are of adequate size for manipulation and inspection.

3. Use symbols appropriate for the structures they represent.

Tapes. The readers for the tapes were professionals who record on a regular basis for the American Printing House for the Blind. Students' major complaint was of excessive lead-in time.

The tapes:

1. Provide adequate lead-in time.

2. Include pauses of sufficient length in the text.

3. Use readers with good voice quality.

4. Provide adequate overall quality.

Labeling and packaging. Labeling of models and packaging of the instructional materials should facilitate self-instruction and independent use. The greatest amount of criticism and questioning came regarding packaging. The materials were not presented to students in production packaging. Models were not labeled since sequencing models was a part of the evaluation.

Expert Teacher Considerations

When a draft of the guidelines had been prepared, the project leader met with a blind resource teacher at the junior high level to review and critique the guidelines. The teacher had previously reviewed the models and tapes, considering those elements which have implications for preparation of self-instructional materials for upper elementary and junior high school students. The teacher had prepared instructional materials, including tapes, for students at these grade levels and had reviewed and evaluated a number of American Printing House materials with taped components. This participating teacher was:

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The teacher reviewer thought that the overall unit organization, the content outline, and the format would be appropriate for developing materials for prebiology students. He agreed generally with the guidelines presented, but expressed some specific concerns related to instruction of younger students. Suggestions and considerations resulting from these sessions follow.

1. The introduction or instruction for use sections should provide a brief review to provide a background for the information presented. Audio-tutorial reference materials in cell division for prebiology students, for example, would briefly review the basic cell.

2. All models should be kept simple and free of raised-line indicators, captions, and information not specifically a part of the model structure displayed.

3. More operational definitions should be provided within the text of the materials.

4. More "tactile" oriented comparisons should be provided when possible.

5. Although the content will often include numerous scientific terms, try to avoid an over-sophisticated presentation in the content.

6. The overview and summary sections should be kept simple with a minimum number of scientific terms used.

7. Some questions should refer to significant events or information contained on previous tapes for review and to provide continuity. There may be a considerable time lapse between the use of the tapes in a series.

8. The question was posed of placing the answers to questions further from the questions and the consideration of a programmed instruction approach.

9. The preparation of a taped glossary should be considered for increasing numbers of poor print and braille readers and for nonreaders.

10. Instructions to students on note-taking should be included either in the program or by the teacher.

Dissemination

In October 1980 the Educational Aids Committee, composed of ex officio trustees of the American Printing House for the Blind, met and approved for production the self-instructional package of meiosis and mitosis models and scripts of the tapes. They specified that the models be constructed in polyurethane. When the materials are produced, a brochure describing them will be circulated to all state departments of instruction (programs for handicapped) and to all residential schools for blind students in the United States. Finally, the project materials will be included in the American Printing House Catalog of Educational and Other Aids which has national and international circulation.

A summary report of the project has been included in the Report of Research and Development Activities at the American Printing House for the Blind (1980) and circulated to ex officio trustees in the above programs for the handicapped. The names of participating experts, supervising teachers, and cooperating schools were included in the report.

A project report has been written. It is anticipated that summarized versions will be submitted to professional journals for publication to inform educators nationally of the availability and content of the program. Information will be made available to Science for the Handicapped at the National Science Teachers Convention, 1981, and an announcement supplied to Science for the Handicapped Newsletter. A project summary will be prepared and submitted to the Division for the Visually Handicapped Newsletter, Council of Exceptional Children, to further inform special educators of the availability of the materials. A similar announcement will be forwarded to the Fountainhead, published by Association for Education of the Visually Handicapped.

Implications for Future Development

A sophisticated set of audio-tutorial reference materials in cell division for blind students was successfully developed and evaluated. The unanimous acceptance of the materials by secondary blind students and their teachers suggests that the materials are appropriate for student use. Implications are for successful development of additional self-instructional reference materials in science for legally blind and for physically handicapped students who have a need for such materials at secondary or college level.

A subordinate objective of the project addressed the development of self-instructional materials for upper elementary and prebiology students in science. Guidelines for such development based on information gained from the project were suggested. The guidelines were adapted from the student/teacher interview forms used in the evaluation of the materials. The potential materials developer can use the guidepoints in each category as checklist items for such development.

References

Ashcroft, S. C. Identification of braille reading errors. Unpublished doctoral dissertation, University of Illinois, 1960.

Berla, E. P., & Murr, M. J. Tactual scanning and memory for a spatial display by blind students. In C. Y. Nolan (Ed.), Facilitating the education of the visually handicapped through research in communications: Part three, facilitating tactile map reading: Final report (Grant No.)EG-0-73-0642). Louisville, Ky.: American Printing House for the Blind, 1976.

Franks, F. L. Instructional materials development in science for the visually handicapped: Institute report. Louisville, Ky.: American Printing House for the Blind, 1970.

Franks, F. L. Educational materials development in primary science: An introductory science laboratory for young blind students. Education of the Visually Handicapped, 1975, 7, 97-101.

Franks, F. L. The tactile modality in adapting and developing science materials for the visually handicapped. In H. Hofman & K. Ricker (Eds.), Science education and the physically handicapped: Sourcebook. Washington, D. C.: National Science Teachers Association, 1979.

Franks, F. L., & Murr, M. J. Biological models for blind students. Journal of Visual Impairment & Blindness, 1978, 72, 121-124.

Gill, J. M., & James, G. A. A study on the discriminability of tactual point symbols, American Foundation for the Blind, Research Bulletin, 1973, No. 26, 19-34.

Heath, W. R. Maps and graphics for the blind: Some aspects of the discriminability of textural surfaces for use in areal differentiation. Unpublished doctoral dissertation, University of Washington, 1958.

Jansson, G. Symbols for tactile maps. In B. Lindqvist & N. Trowald (Eds.), European conference of educational research for the visually handicapped. Project: PUSS: VIII. Report No. 31, 1972.

Lederman, S. J., & Taylor, M. M. Fingertip force, surface geometry, and the perception of roughness by active touch. Perception & Psychophysics, 1972, 12, 401-408.

Meyers, E., Ethington, D., & Ashcroft, S. Readability of braille as a function of three spacing variables. Journal of Applied Psychology, 1958, 42, 163-165.

Nolan, C. Y. Relative legibility of raised and incised tactual figures. Education of the Visually Handicapped, 1971, 3, 33-36.

Nolan, C. Y., & Kederis, C. J. Perceptual factors in braille word recognition. American Foundation for the Blind, Research Series, 1969, No. 20.

Nolan, C. Y., & Morris, J. E. Tactual symbols for the blind: Final report (OVR-RD-587). Louisville, Ky.: American Printing House for the Blind, 1963.

Nolan, C. Y., & Morris, J. E. Development and validation of the Roughness Discrimination Test. International Journal for the Education of the Blind, 1965, 15, 1-6.

Nolan, C. Y., & Morris, J. E. Improvement of tactual symbols for blind children: Final report (Project No. 5-042); Grant No. OEG-32-37-0000-1012). Louisville, Ky.: American Printing House for the Blind, 1971. (ERIC Document Reproduction Service No. ED 070 228).

Schiff, W. Raised line drawing research project: Final report. New York: Recording for the Blind, 1966.

Schiff, W., & Isikow, H. Stimulus redundancy in the tactile perception of histograms. International Journal for the Education of the Blind, 1966, 196, 1-11.

Schiff, W., Kaufter, L., & Mosak, S. Informative tactile stimuli in the perception of direction. Perceptual & Motor Skills, 1966, 23 (3, Pt. 2), 1315-1335.

Sherman, J. C. Needs and resources in maps for the blind. New Outlook for the Blind, 1965, 59, 130-134.

Weiner, L. The performance of good and poor braille readers. International Journal for the Education of the Blind, 1963, 12, 72-77.

Weinstein, S. Intensive and extensive aspects of tactile sensitivity as a function of body part, sex, and laterally. In D. R. Kenshalo (Ed.), The skin senses. Springfield, Ill.: Charles C. Thomas, 1968.

Wiedel, J. W. Tactual maps for the visually handicapped: Some developmental problems. New Outlook for the Blind, 1969, 63, 80-88.

Wiedel, J. W., & Groves, P. A. Tactual mapping: Design, reproduction, reading and interpretation: Final report (SRS Grant No. RD-2557-S). College Park, Md.: University of Maryland (Department of Geography), 1969.

APPENDIX A

References

College Textbooks and Journal Articles

Adams, P. Biology today. New York: Random House, 1972.

Avers, C. J. Cell biology. New York: D. Van Nostrand, 1976.

Chiappetta, V. J., & Greulach, V. A. (Eds.). Biology, the science of life. Morristown, N. J.: Silver Burdette, 1977.

Crouch, J. E., & McClintic, J. R. Human anatomy and physiology (2nd ed.). New York: John Wiley & Sons, 1976.

Dyson, R. D. Essentials of cell biology (2nd ed.). Boston, Ma.: Allyn & Bacon, 1978.

Erickson, J. What is the centromere? American Biology Teacher, 41 (1), 40-43, January, 1979.

Ford, J. E., & Monroe, J. E. Living systems, principles and relationships (3rd ed.). New York: Harper & Row, 1977.

Hardin, G. & Bejema, C. Biology, its principles and implications (3rd ed.). San Francisco, Ca.: W. H. Freeman, 1978.

Jones, K. C., & Gaudin, A. J. Introductory biology. New York: John Wiley & Sons, 1977.

McElroy, W. & Swanson, C. P. Foundations of biology. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Novikoff, A. B., & Holtzman, E. Cells and organelles. New York: Holt, Rinehart & Winston, 1970.

Sheer, B. T. Patterns of life. New York: Harper's College Press, 1977.

Swanson, C. P., & Webster, P. L. The cell (4th ed.). Englewood Cliffs, N. J.: Prentice-Hall, 1977.

Tortora, G. J., & Becker, J. F. Life science. New York: Macmillian, 1972.

Villee, C. A. Biology (7th ed.). Philadelphia, Pa.: W. B. Saunders, 1977.

Winchester, A. M. Genetics: A survey of the principles of heredity. Boston, Ma.: Houghton Mifflin, 1972.

Wolfe, S. L. Biology of the cell. Belmont, Ca.: Wadsworth Publishing, 1972.

Secondary School Textbooks

Biological science, an ecological approach (3rd ed.). Chicago: Rand McNally, 1973.

Biological science, an inquiry into life. New York: Harcourt Brace Jovanovich, 1973.

Biological science, interaction of experiments and ideas (2nd ed.). Englewood Cliffs, N. J.: Prentice-Hall, 1970.

Biological science molecules to man (3rd ed.). Boston, Ma.: Houghton Mifflin, 1976.

Biological science, patterns and processes. New York: Holt, Rinehart & Winston, 1966.

Frazier, R. P., & Smith, H. A. The biological sciences, interpreting man's environment. River Forest, Il.: Laidlaw Brothers, 1971.

Heimler, C. H. Focus on life science (2nd ed.). Columbus, Oh.: Charles E. Merrill, 1974.

Hood, L. E., Wilson, J. H., & Wood, W. B. Molecular biology of eucaryotic cells (Vol. I). Menlo Park, Ca.: W. A. Benjamin, 1975.

Hopkins, C. R. Structure and function of cells. Philadelphia, Pa.: W. B. Saunders, 1978.

Kimball, J. W. Biology (3rd ed.). Reading, Ma.: Addison-Wesley Publishing, 1974.

Moore, H. A., & Carlock, J. R. The spectrum of life. New York: Harper & Row, 1970.

Oram, R. F. Biology, living systems (2nd ed.). Columbus, Oh.: Charles E. Merrill, 1976.

Otto, J. H., Towle, A., & Madnick, M. E. Modern biology (Teacher's Edition). New York: Holt, Rinehart & Winston, 1977.

Smallwood, W. A., & Green, E. R. Biology. Morristown, N. J.: Silver Burdett, 1974.

Swanson, C. P. & Webster, P. L. The cell (4th ed.). Englewood Cliffs, N. J.: Prentice-Hall, 1977.

Weinberg, S. L. Biology, an inquiry into the nature of life. Boston, Ma.: Allyn & Bacon, 1971.

Weinberg, S. L., & Kalish, A. Biology, an inquiry into the nature of life. Boston, Ma.: Allyn & Bacon, 1974.

APPENDIX B

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